Gas Stoichiometry Problems

For the following, if no P or T is given, then use P = 101.3 kPa and T = 298 K.

1) Calcium carbonate decomposes at high temperatures to form carbon dioxide and calcium oxide. How many grams of calcium carbonate will be needed to form 3.45 liters of carbon dioxide? (14.1 g)

$$\underset{m = ?}{CaCO_{3(s)}} \rightarrow \underset{V = 3.45\ L}{CO_{2(g)}} + \underset{}{CaO_{(s)}}$$

$M = 100.09\ g/mol$ $\quad P = 101.3\ kPa$ $\quad T = 298\ K$

$$m_{CaCO_3} = \frac{PV}{RT} \times \frac{\#\,mol\ CaCO_3}{\#\,mol\ CO_2} \times M_{CaCO_3}$$

$$= \frac{101.3\ kPa \times 3.45\ L}{8.314\ kPa \cdot L \cdot mol^{-1} \cdot K^{-1} \times 298\ K} \times \frac{1\,mol\ CaCO_3}{1\,mol\ CO_2} \times \frac{100.09\ g}{1\,mol\ CaCO_3}$$

$$= 14.1\ g$$

2) Ethylene burns in oxygen to form carbon dioxide and water vapor. How many liters of water can be formed if 1.25 liters of ethylene are consumed in this reaction? (2.50 L)

$$\underset{V = 1.25\ L}{C_2H_{4(g)}} + \underset{}{3\,O_{2(g)}} \rightarrow \underset{}{2\,CO_{2(g)}} + \underset{V = ?}{2\,H_2O_{(l)}}$$

$P = 101.3\ kPa$ $\quad T = 298\ K$ $\quad P = 101.3\ kPa$ $\quad T = 298\ K$

$$V_{H_2O} = V_{C_2H_4} \times \frac{\#\,mol\ H_2O}{\#\,mol\ C_2H_4}$$

$$= 1.25\ L \times \frac{2\,mol\ H_2O}{1\,mol\ C_2H_4}$$

$$= 2.50\ L$$

3) When chlorine is added to acetylene, 1,1,2,2-tetrachloroethane is formed. How many liters of chlorine will be needed to make 75.0 grams of $C_2H_2Cl_4$? (21.9 L)

$$\underset{V = ?}{2\,Cl_{2(g)}} + \underset{}{C_2H_{2(g)}} \rightarrow \underset{m = 75.0\ g}{C_2H_2Cl_{4(l)}}$$

$P = 101.3\ kPa$ $\quad M = 167.84\ g/mol$

$T = 298\ K$

$$V_{Cl_2} = \frac{m_{C_2H_2Cl_4}}{M_{C_2H_2Cl_4}} \times \frac{\#\,mol\ Cl_2}{\#\,mol\ C_2H_2Cl_4} \times \frac{RT}{P}$$

$$= 75.0\ g \times \frac{1\,mol\ C_2H_2Cl_4}{167.84\ g} \times \frac{2\,mol\ Cl_2}{1\,mol\ C_2H_2Cl_4} \times \frac{8.314\ kPa \cdot L \cdot mol^{-1} \cdot K^{-1} \times 298\ K}{101.3\ kPa}$$

$$= 21.9\ L$$

4) Methane, CH_4, gas can be made in small quantities by the reaction shown below. How many ml of $CH_4(g)$, at STP will be produced when 1.73 grams of aluminum carbide, Al_4C_3, completely react with water? (808 mL)

$$\underset{m = 1.73\ g}{Al_4C_{3(s)}} + 12\ H_2O_{(l)} \rightarrow 4\ Al(OH)_{3(aq)} + \underset{V = ?}{3\ CH_{4(g)}}$$

$M = 143.95\ g/mol$ $\qquad V_{STP} = 22.4\ L/mol$

$$V_{CH_4} = \frac{m_{Al_4C_3}}{M_{Al_4C_3}} \text{ x } \frac{\#\text{mol } CH_4}{\#\text{mol } Al_4C_3} \text{ x } V_{STP}$$

$$= 1.73\ g \text{ x } \frac{1\ \text{mol } Al_4C_3}{143.95\ g} \text{x } \frac{3\ \text{mol } CH_4}{1\ \text{mol } Al_4C_3} \text{ x } \frac{22.4\ L}{1\ \text{mol } CH_4}$$

$$= 0.808\ L = 808\ mL$$

5) Carbon dioxide gas can be produced by the action of sodium chlorite upon glucose according to the equation given below. If 323 ml of carbon dioxide, CO_2, at STP, came from the reaction, how many grams of glucose, $C_6H_{12}O_6$, reacted? (0.433 g)

$$\underset{m = ?}{C_6H_{12}O_{6(s)}} + 6\ NaClO_{2(aq)} \rightarrow \underset{V = 323\ mL = 0.323\ L}{6\ CO_{2(g)}} + 6\ NaCl_{(aq)} + 6\ H_2O_{(s)}$$

$M = 180.18\ g/mol$ $\qquad V_{STP} = 22.4\ L/mol$

$$m_{C_6H_{12}O_6} = V_{CO_2} \text{ x } \frac{1}{V_{STP}} \text{ x } \frac{\#\text{mol } C_6H_{12}O_6}{\#\text{mol } CO_2} \text{ x } M_{CaCO_3}$$

$$= 0.323\ L \text{ x } \frac{1\ \text{mol } CO_2}{22.4\ L} \text{ x } \frac{1\ \text{mol } C_6H_{12}O_6}{6\ \text{mol } CO_2} \text{ x } \frac{180.18\ g}{1\ \text{mol } C_6H_{12}O_6}$$

$$= 0.433\ g$$

6) The element boron, B, reacts with sulfur dioxide gas, SO_2, to produce boron(III) oxide, B_2O_3, and sulfur, S, according to the following equation. How many grams of boron(III) oxide will be produced if 816 mL of SO_2 at 737 mm Hg pressure and 18°C react (1.54 g)

$$4\ B_{(s)} + \underset{\substack{V = 816\ mL = 0.816\ L \\ P = 737\ mmHg = 98.3\ kPa \\ T = 18.0\ ^\circ C = 291.2\ K}}{3\ SO_{2(g)}} \rightarrow \underset{\substack{m = ? \\ M = 69.62\ g/mol}}{2\ B_2O_{3(g)}} + 3\ S_{(s)}$$

$$m_{B_2O_3} = \frac{PV}{RT} \text{ x } \frac{\#\text{mol } B_2O_3}{\#\text{mol } SO_2} \text{ x } M_{B_2O_3}$$

$$= \frac{98.3\ kPa \text{ x } 0.816\ L}{8.314\ kPa \cdot L \cdot mol^{-1} \cdot K^{-1} \text{ x } 291.2\ K} \text{ x } \frac{2\ \text{mol } B_2O_3}{3\ \text{mol } SO_2} \text{ x } \frac{69.62\ g}{1\ \text{mol } B_2O_3}$$

$$= 1.54\ g$$

7) Aluminum phosphide, AlP, reacts with oxygen gas, O_2, making aluminum oxide, Al_2O_3, and phosphorous(V) oxide, P_4O_{10}. What volume of oxygen gas at 879.0 torr and 31.0 °C will be needed to produce 3.76 g of aluminum oxide? (3180 mL)

$$4\,AlP_{(s)} + 8\,O_{2(g)} \rightarrow 2\,Al_2O_{3(s)} + P_4O_{10(g)}$$

$V = ?$ $\quad m = 3.76\ g$

$P = 879.0\ torr = 117.2\ kPa$ $\quad M = 101.96\ g/mol$

$T = 31.0\ ^\circ C = 304.2\ K$

$$V_{O_2} = \frac{m_{Al_2O_3}}{M_{Al_2O_3}} \times \frac{\#mol\ O_2}{\#mol\ Al_2O_3} \times \frac{RT}{P}$$

$$= 3.76\ g \times \frac{1\,mol\ Al_2O_3}{101.96\ g} \times \frac{8\,mol\ O_2}{2\,mol\ Al_2O_3} \times \frac{8.314\ kPa \cdot L \cdot mol^{-1} \cdot K^{-1} \times 304.2\ K}{117.2\ kPa}$$

$$= 3.18\ L = 3{,}180\ mL$$

8) Magnesium reacts vigorously with phosphorous acid to produce magnesium phosphate and hydrogen. When 5.25 g of Mg reacts with 100. mL of 1.50 M H_3PO_4 at 91.7 kPa and 15.0 °C react, how many litres of hygrogen gas will be produced? (5.64 L)

$$3\,Mg_{(s)} + 2\,H_3PO_{4(aq)} \rightarrow Mg_3(PO_4)_{2(s)} + 3\,H_{2(g)}$$

$$3\,Mg_{(s)} + 2\,H_3PO_{4(aq)} \rightarrow Mg_3(PO_4)_{2(s)} + 3\,H_{2(g)}$$

$m = 0.525\ g$ $\quad V = 100.\ mL = 0.100\ L$ $\quad V = ?$

$M = 24.31\ g/mol$ $\quad C = 0.150\ mol/L$ $\quad P = 91.7\ kPa$

$T = 15.0\ ^\circ C = 288.2\ K$

i) Using Mg

$$V_{H_2}(Mg) = \frac{m_{Mg}}{M_{Mg}} \times \frac{\#mol\ H_2}{\#mol\ Mg} \times \frac{RT}{P}$$

$$= 5.25\ g \times \frac{1\,mol\ Mg}{24.31\ g} \times \frac{3\,mol\ H_2}{3\,mol\ Mg} \times \frac{8.314\ kPa \cdot L \cdot mol^{-1} \cdot K^{-1} \times 288.2\ K}{91.7\ kPa}$$

$$= 5.64\ L$$

ii) Using H_3PO_4

$$V_{H_2}(H_3PO_4) = CV \times \frac{\#mol\ H_2}{\#mol\ H_3PO_4} \times \frac{RT}{P}$$

$$= \frac{1.50\ mol\ H_3PO_4}{L} \times 0.100\ L \times \frac{3\,mol\ H_2}{2\,mol\ H_3PO_4} \times \frac{8.314\ kPa \cdot L \cdot mol^{-1} \cdot K^{-1} \times 288.2\ K}{91.7\ kPa}$$

$$= 5.88\ L$$

$\therefore$ Mg is the L.R. and 5.64 L of hydrogen is produced.